# EE-434 Power Electronics

Engr. Dr. Hadeed Ahmed Sher

Ghulam Ishaq Khan Institute of Engineering Sciences and Technology
Topi 23460, Pakistan

*hadeed@giki.edu.pk*

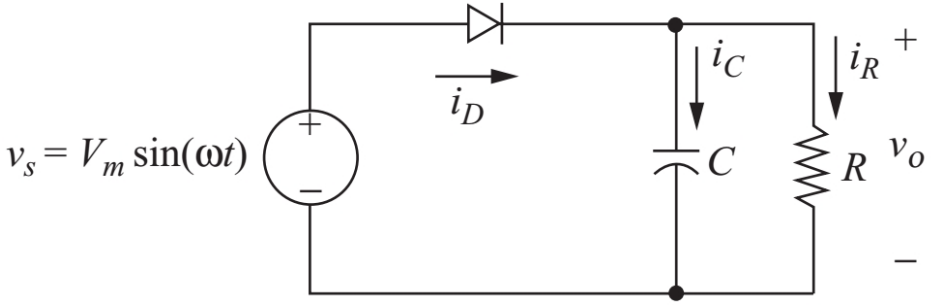
May 28, 2020

# Overview

1. Half wave rectifier — C filter
   - Assumptions
   - Analysis
   - Capacitor current
   - Peak diode current
   - Voltage ripple

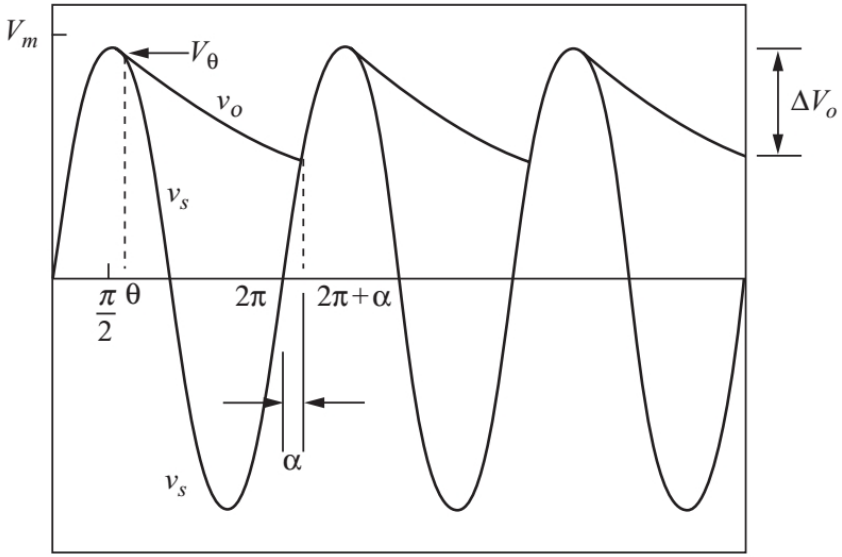
# Half wave rectifier — C filter

Figure shows an RC parallel branch at the output of a half wave rectifier.




Capacitor reduces the variations in the output voltage, thus creating a more like DC.

# Half wave rectifier — C filter




Let the capacitor has zero charge before the application of ac input. The diode will become F.B as soon as the anode to cathode voltage exceeds the threshold. With a F.B diode, the load voltage becomes equal to the source voltage.

Capacitor is charged till the peak voltage $V_m$ at $\omega t = \pi/2$.
After this point, the source voltage begins to reduce, and capacitor begins to discharge in the load resistor.
When the source voltage decreases to an extent that the diode becomes R.B then the source is disconnected and the load is supplied solely by the capacitor.
The discharge of the capacitor depends entirely on the time constant RC.

# Half wave rectifier — C filter

The comparison of rate of change of input voltage and the capacitor voltage hints the time when the diode becomes R.B (It is $\theta$).
The output voltage with diode ON is expressed as

$$v_o(\omega t) = V_m sin\omega t \tag{1}$$

The output voltage with diode OFF is expressed as

$$v_o(\omega t) = V_\theta e^{-(\omega t-\theta)/\omega RC} \tag{2}$$

where, $V_\theta = V_m sin\theta$.
The derivative(slope) of these are

$$\frac{d}{d(\omega t)}[V_m sin\omega t] = V_m cos\omega t \tag{3}$$

# Half wave rectifier — C filter

$$\frac{d}{d(\omega t)}[V_m sin\theta e^{-(\omega t-\theta)/\omega RC}] = V_m sin\theta\left(\frac{-1}{\omega RC}\right)e^{-(\omega t-\theta)/\omega RC} \tag{4}$$

At $\omega t = \theta$ the slopes are equal. So substituting $\omega t = \theta$ in (3) and (4),

$$V_m cos\theta = \left(\frac{V_m sin\theta}{-\omega RC}e^{(-\theta-\theta)/\omega RC}\right) = \frac{V_m sin\theta}{-\omega RC} \tag{5}$$

This becomes

$$\frac{V_m cos\theta}{V_m sin\theta} = \frac{1}{-\omega RC} \implies \frac{1}{tan\theta} = \frac{1}{-\omega RC} \tag{6}$$

Solving for $\theta$

$$\theta = tan^{-1}(-\omega RC) = -tan^{-1}(\omega RC) + \pi \tag{7}$$

If $\tau$ is large, then

$$\theta \approx \pi/2 \tag{8}$$

# Half wave rectifier — C filter

During the next positive half cycle, the diode becomes F.B not at $\omega t = 2\pi$ but at $\omega t = 2\pi + \alpha$.
Using basic current voltage expressions for R and C, the current can be calculated.

$$i_C(t) = C\frac{dv_o(t)}{dt} \tag{9}$$

$$i_C(\omega t) = \omega C\frac{dv_o(\omega t)}{d(\omega t)} \tag{10}$$

Using the expressions of (1) and (2), the expression for $\theta \leq \omega t \leq 2\pi + \alpha$ when diode is OFF,

$$i_C(\omega t) = -\left(\frac{V_m sin\theta}{R}\right)e^{-(\omega t-\theta)/\omega RC} \tag{11}$$

For $2\pi + \alpha \leq \omega t \leq 2\pi + \theta$ when diode is ON

$$i_C(\omega t) = \omega C V_m cos(\omega t) \tag{12}$$

# Half wave rectifier — C filter

The source current is the sum of capacitor current and the load resistor current. This is the current that flows through the diode as well, therefore the diode must be rated at the peak source current that flows.
The problem with the C filter is the peak current that flows whenever the diode first turns on.
Under steady state condition, the peak diode current flows at $\omega t = 2\pi + \alpha$. Using (7),

$$I_{C,peak} = \omega C V_m cos(2\pi + \alpha) = \omega C V_m cos\alpha \tag{13}$$

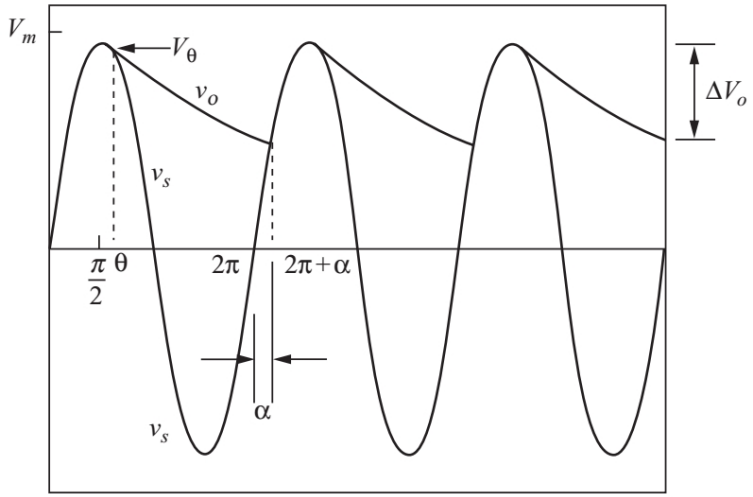
$$I_R(2\omega t + \alpha) = \frac{V_m sin(2\omega t + \alpha)}{R} = \frac{V_m sin\alpha}{R} \tag{14}$$

Thus, the sum of (13) and (14) provides the peak diode current

$$I_{D,peak} = V_m \left( \omega C \ cos\alpha + \frac{sin\alpha}{R} \right) \tag{15}$$

# Half wave rectifier — C filter

In terms of the output voltage ripple, the maximum voltage and minimum voltage values are important.




$$\Delta V_o = V_{max} - V_{min} = V_m - V_m sin\alpha = V_m(1 - sin\alpha) \tag{16}$$

In terms of component values,

$$\Delta V_o = \frac{V_m}{fRC} \tag{17}$$

As C is increased, the ripple and conduction time of diode decreases. This increases the peak diode current .